reviewed paper

A new Approach in the Visualization of Georeferenced Sensor Data in Spatial Planning

Frank Michel, Daniel Steffen, Benjamin S. Bergner, Jan-Philipp Exner, Peter Zeile

(Dr. Frank Michel, DFKI GmbH, Trippstadter Str. 122, 67663 Kaiserslautern, Germany, dr.frank.michel@gmail.com)
(Dipl.-Inf. Daniel Steffen, DFKI GmbH, Trippstadter Str. 122, 67663 Kaiserslautern, Germany, daniel.steffen@dfki.de)
(Dipl.-Ing. Benjamin S. Bergner, University of Kaiserslautern, Urban Sociology, bergner.benjamin@t-online.de)
(Dipl.-Ing. M.Sc. Jan-Philipp Exner, University of Kaiserslautern, CPE, exner@rhrk.uni-kl.de)
(Dr.-Ing. Peter Zeile, University of Kaiserslautern, CPE, zeile@rhrk.uni-kl.de)

1 ABSTRACT

There are multiple ways to visualize geotagged information. The most commonly used tools are GIS (Geospatial Information Systems) to show the data on a 2D map. For 3D visualization of geospatial information only a few systems exist, e.g. Google Earth, NASA World Wind, etc., which only provide basic visualization techniques and also only allow to visualize a small number of data attributes at the same time. In addition the user has to put a lot of effort into producing meaningful visualizations to be able to compare and analyze the data. In this paper we present a new approach to the visualization of geotagged sensory data in the context of spatial planning. We use a tool called GeoVisualizer, which aims at providing planners the possibility to show and analyze their multivariate sensory data in a 3D geospatial context.

In a cooperation project between DFKI and CPE, a variety of human sensory assessment test data sets, recorded with the BMS Smartband, were visualized. The Smartband is a small wristband that can detect negative arousals of test people. In combination with a GPS device, it is possible to geotag "stress hotspots" in a city. Recorded situations in this paper are for example how people feel during a hike in the forest, watching a football game, going through the city in crowded situations or walking along a touristic path. The focus of the presented new workflow is not only to integrate sensor data, but also traditional sources like WebMapSevices and 3D-content from KMZ files in order to combine them in a way which can be used for various kinds of urban planning projects. The paper will give a short overview of GeoVisualizer and present a planner's workflow how to integrate their data and how they can edit the look of the integrated data in a fast and easy way.

2 INTRODUCTION

The visualization of sensor-based geotagged data in spatial planning increased considerably in the last few years. Virtual globe systems like NASA World Wind and Google Earth, virtual 3D-city models as well as new approaches of immersive techniques became important not only in spatial planning, but also gain increasing importance in social, cultural and everyday context (ZEILE 2010). According to experts, virtual globes became a 3D-GIS standard (RUSH 2006), and stimulated the discussion about visualization and benefits of geodata for all user groups, even besides spatial planning (ZEILE 2010).

Last but not least with the help of automated calculation of traffic density, supported by the data of mobile phone users and the works of MIT SENSEable City Labs like LIVE Singapore! and Copenhagen Wheel (MARTINO ET AL. 2010, RESCH ET AL. 2011) this field of research entered general publicity. These systems present the vision, what would be possible with these techniques in the future, but they are still not designed for daily use. In practice, planners need a tool, which can import sensor data and visualize them in realtime in an easy way. This easy to use feature is essential, because the results of these sensor based data should be used in political decision processes and serve as a basis for communication between planners and stakeholders.

One solution is the "GeoVisualizer" which delivers very good results for this kind of work in a planning context. In this paper, some use cases will be presented which were results of a cooperation project about "human sensory assessment" between DFKI and the University of Kaiserslautern, CPE. In these use cases, all data belong to the research field of "spatial psychophysiological monitoring". Metaphorically, the „Citizen as Sensor" (GOODCHILD 2007) learns to walk virtually. The required methods and techniques, in an especially tailored workflow for spatial planning, will be presented in the following chapters.

3 STATE OF THE ART

Following some backgrounds and state of the art developments concerning the research field of Digital Globes / Virtual Earth Browser as well as state of research in the field of psychophysiological urban monitoring (measurement of humans' emotions in urban environment/ human sensory assessment) were elaborated.

3.1 Visualizing Geodata and Virtual Earth Browser

The most important prerequisite for planning activities was and is knowledge that planners collect, sort, constantly renew and prepare to get complex and compressed information for a specific planning decision (STREICH 2005:11). Digital Globe Systems meet these requirements and offer the possibilities to planners to get own spatial information to geotag a special planning task and redistribute these datasets to a specific circle of users (ZEILE 2010). The idea of a "digital earth" was described for the first time in 1991 by Neal Stephensons' novel „Snow Crash": „A globe about the size of a grapefruit, a perfectly detailed rendition of Planet Earth, hanging in space at arm's length (…) It is a piece of (…) software called, simply, Earth. It is the user interface that (…) uses to keep track of every bit of spatial information that it owns -- all the maps, weather data, architectural plans, and satellite surveillance" (STEPHENSON 1992: 127).

In 1994, the Berlin company ART+COM developed „TerraVision", inspired by Stephensons' novel as a standalone system on SGI-units. TerraVision is a 1:1 virtual copy of planet earth. One significant feature of TerraVision is the human machine interface. With the help of an interface, designed like a globe, the so called Earthtracker, the user gets the possibility to navigate to every desired spot on earth interactively and in realtime over the virtual globe (ART+COM 1994).

The first and free consumer based virtual globe system was developed by NASA and was called World Wind (NASA 2013). For the first time, it was possible to import and export spatial data through a user interface. In addition, the integration of Web Map Services and the visualization of textured meshes were realized. Keyhole Earth Browser, in the beginning operated by Keyhole, was the initiation point for the development of Google Earth, which is today the best-known and widespread software for digital globes. As associated programming language, the Keyhole Markup Language (KML), also developed by Keyhole, is established as an Open Geospatial Consortium (OGC) standard by now.

All the above-mentioned systems offer different import and export functions, but there are only a few options to develop some additional new types of visualization. There are some software tools available, which can transform collected data into 3D visualizations, which need to be combined manually for an appealing look. An integrated and interactive 3D-GIS application, which allows the easy integration, visualization and animation of heterogeneous data is not available today.

3.2 Human Sensory Assessment

Human sensory assessment in spatial planning is based on the approach to use people as sensors and at the same time as producers for emotional data in real time (Exner et al. 2011). This approach aims to deepen the knowledge of continuous interdependencies between humans and their environment. Here, the aim is to identify specific stress-inducing structural or environmental situations and also places having positive effects on the well-being. Based on this, comprehensive measures can be identified to optimize the respective study area.

The used sensor for the measurement of human emotions is the BMS Smartband (Papastefanou 2009), which is used to detect psychophysiological values of the body according to the environmental circumstances. The approach of psychophysiological monitoring enables to correlate physiological data (e.g., skin temperature and skin conductance changes) to emotional states of the people (Kreibig 2010). A GPS-logger is used additionally for simultaneous localization of the emotional data.

The major challenge is to get the combined spatial data across to decision makers as well as visualizing it adequately for the academic sector. Existing visualization software reaches its limit especially when multiple data attributes have to be visualized simultaneously. For that reason, it is interesting for the academic sector to visualize various data attributes within a presentation, either individually or simultaneously. This includes, the skin temperature, skin conductance, and the combination of both which can be used to derive stress events. Policy makers on the other hand want focused information that is limited to the essential content.

Until now, many manual steps had to be made with various software products such as ArcGIS, the GPS-Visualizer or Google Earth to achieve a high quality and precise visualization of georeferenced human sensory data. That complex procedure was accompanied with a large amount of time.

4 GEOVISUALIZER

3D data visualization is a common feature of modern GIS. There are a multitude of standalone applications as well as plugins allowing the user to visualize his three dimensional data in a geographic context. However, the use of state of the art visualization techniques and methods are usually reserved for expert users due to the complex nature and complicated setup of these visualizations. This is where GeoVisualizer ties in by giving even non-visualization experts the tools and possibilities to produce meaningful visualizations based on state of the art techniques and to get a better insight into the underlying georeferenced data.

GeoVisualizer is based on the Open-Source NASA World Wind SDK (NASA 2013) which provides a 3D virtual globe and different import plugins for geodata. In addition, GeoVisualizer is realized with the Java Web Start Technologie (ORACLE 2013a), which allows starting the application on every computer connected to the internet and providing the basic Java libraries. Once installed, GeoVisualizer resides on the hard disk of the computer and can be run in offline mode. However, if the computer is connected to the internet GeoVisualizer will execute a check for updates to ensure that the user always has the latest, up to date components.

GeoVisualizer uses an intuitive and easy to use graphical user interface (GUI) as well as a flexible and extendable architecture for the visualization of 3D and 4D (3D plus time) georeferenced data sets. Using the time dimension allows animated presentations and the interactive exploration and analysis of the data.

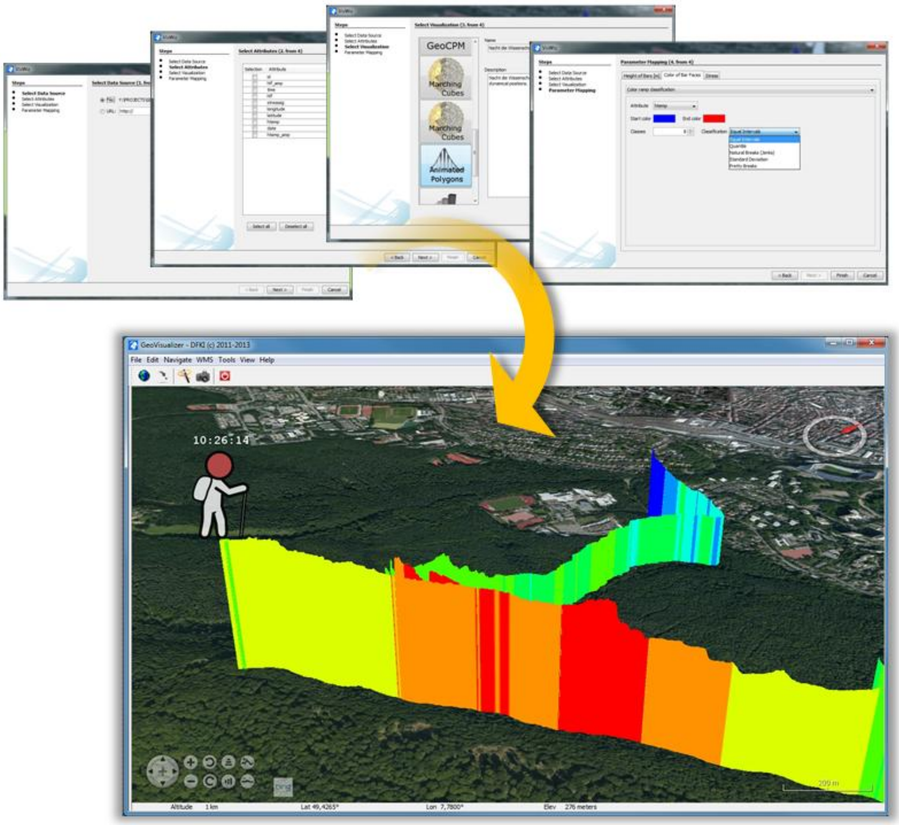

Figure 1: By using the visualization wizard "VisWiz" (top) the user is able to produce different 3D visualizations without the need of expert knowledge (bottom).

4.1 GeoVisualizer Components

GeoVisualizer is split into two main components, the GeoVisualizer-UI and GeoVisualizer-Core.

The GeoVisualizer-UI component provides the necessary methods and functions for the graphical user interface. Besides the functionalities like the integration and management of GIS web services (i.e. Web Map Service and Web Feature Service) already integrated into the NASA World Wind SDK, the component provides the visualization wizard VisWiz which guides the user through the process of generating 3D and 4D representations based on his own data (see Figure 1). In addition, the GeoVisualizer-UI allows the use of stereoscopic displays (Side-by-Side, horizontal and vertical interlaced) for presenting the visualization on real 3D hardware.

The GeoVisualizer-Core component provides the basic visualization techniques and the interface specification for the extension of the application with new visualization techniques for different georeferenced data sets. The interface uses the Service Provider Interfaces (SPI) (ORACLE 2013b) which allows the easy integration of new extensions. Within GeoVisualizer SPI is used to integrate user specific visualizations, data import and export modules. The combination of Java Web Start and SPI technologies allows the use of private, local visualization concepts next to the always up to date public GeoVisualizer components. Besides the basic visualization techniques (e.g. point clouds) the GeoVisualizer-Core component provides different color palettes and color encodings (see e.g. BREWER 2013). For more details on the technical implementation of GeoVisualizer please refer to (STEFFEN ET AL. 2013).

4.2 Visualization Components

Within this cooperation project, we developed different visualizations for static, stationary as well as dynamic sensor data. The two visualization extensions “Animated Polygons” and “Scrolling 3D Bars” are depicted in Figure 2. “Animated Polygons” (see Figure 2 left) is used for the visualization of continuous-dynamic or spatio-temporal data. To visualize time-dependent variables “Animated Polygons” offers the attributes height, color and spatial position of the polygon. All time steps are visualized and a new time step usually refers to a new spatial position.

For the presentation of continuous-static sensor data “Scrolling 3D bars” has been implemented as a visualization extension (see Figure 2 right). Attributes for mapping different variables are height, depth, width and color of the three-dimensional column. As the position of the sensor data is static, older data points are moved (scrolled) away from the spatial location, so the latest time step is always visualized at the real data position. In contrast to the “Animated Polygons”, only a user defined time span is shown, e.g. the last 10 time steps.

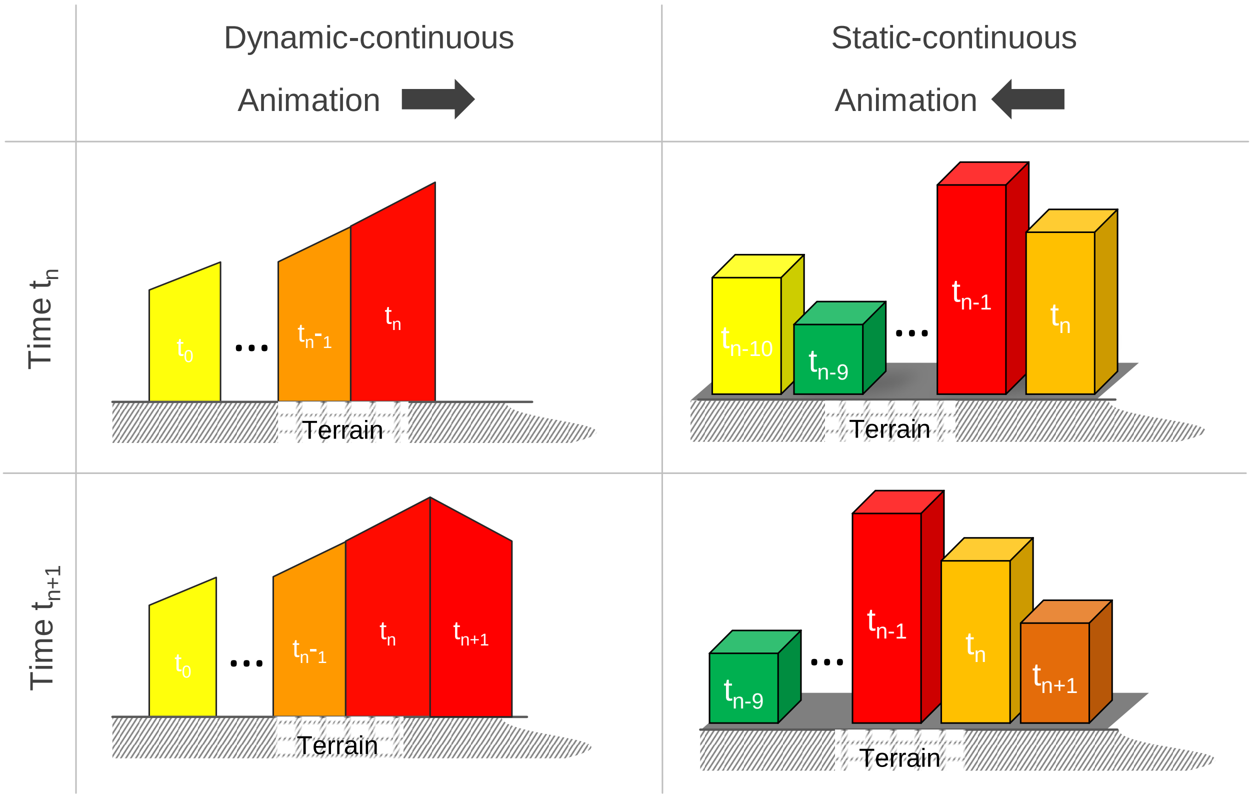

Figure 2: Visualization „Animated Polygons“ (left) and „Scrolling 3D Bars“ (right) for time steps t_n and t_{n+1}.

5 WORKFLOW FOR PLANNERS

The planner is relying on clear and understandable visualizations for the presentation of his complex analysis. The workflow to achieve this goal consists of a number of individual steps (see Figure 3). This embraces the equipment of test people with various kinds of sensor devices, the measurement of the data as well as its analysis and interpretation. As a first step, the determination of the required data is necessary. For the case studies mentioned this means that relevant geodata (the tracked paths), human sensory data, personal video material and data extracted from the questionnaires must be processed and merged. For correlating geodata with human sensory data (skin conductance, skin temperature), it is necessary to use statistical methods (statistical outlier removal, smoothing, scoring) to clean the human sensory data.

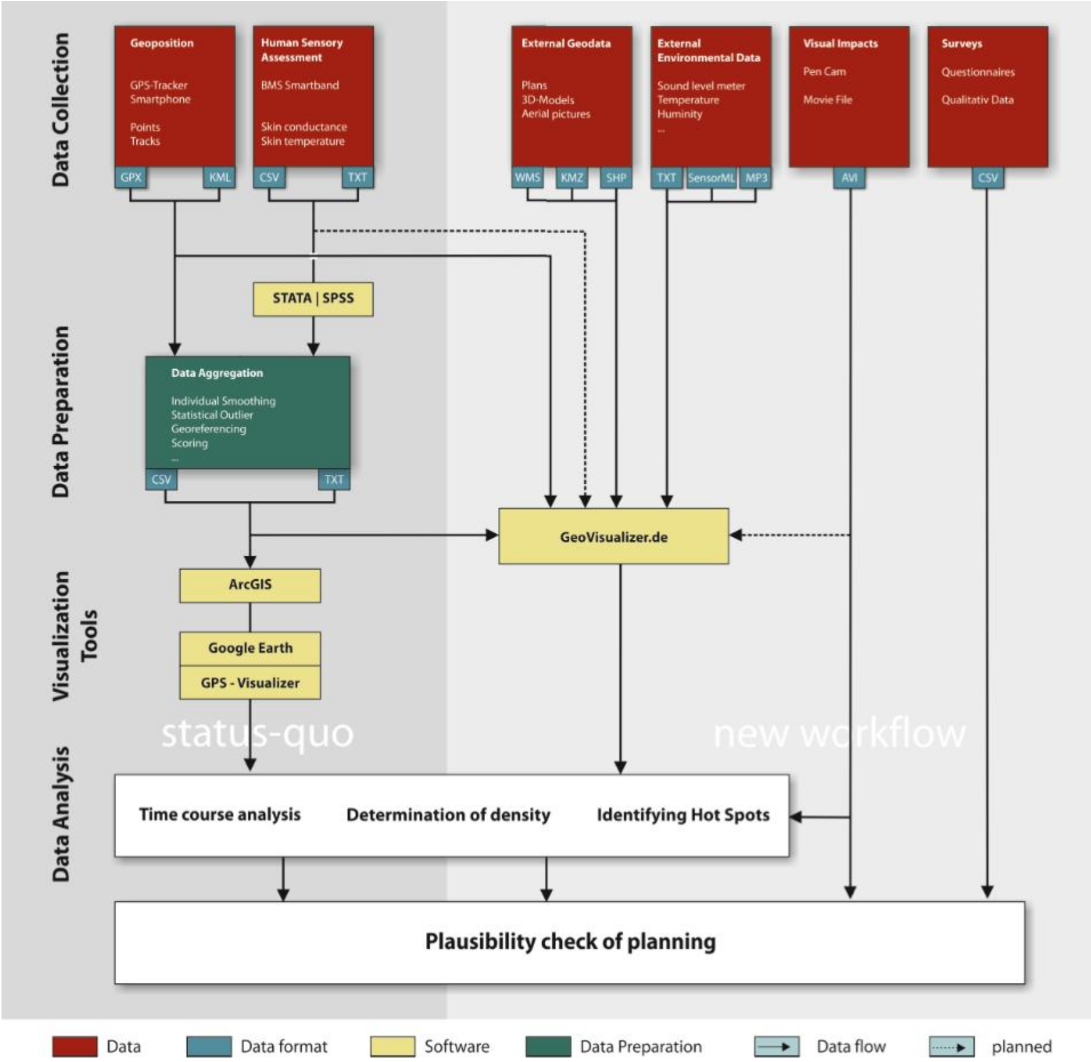

Figure 3: Workflow Human Sensory Assessment & GeoVisualizer (Source OWN FIGURE 2013)

In previous studies, the workflow for visualization was separated in complicated steps with different data formats using different programs. Statistical methods and geodata-analysis had to be made separately and were merged together under a complex approach. By using GeoVisualizer it is now possible to combine these steps into one workflow within a single software solution. The GeoVisualizer can easily read and process different data formats. This embraces data like various kinds of geodata (e.g. SHPs, KMLs) and external environmental sensor data like temperature or humidity for example. The functionalities replace the need for the obligatory use of ArcGIS or Google Earth at this point. The necessary statistical methods will be also part of the GeoVisualizer in the future.

In test studies Shapefiles with embedded emotional data were created. .The GeoVisualizer is able to represent the respective attributes directly with his component VisWiz. It provides a variety of different visualization options as output, such as timing analysis or density determination of e.g. stress responses. Stress hotspots of test people or other spatial patterns can be identified and a plausibility check for planning purposes of the examined phenomenon can be made.

6 INTEGRATION OF SENSOR DATA – USE CASES

In order to test the developed approaches, suitable use cases were designed. Following a pre-study, the first test study took place during a football match. It provides interdependencies between external triggers inducing emotional reactions and the immediate environment. In the case studies, the measured and derived physiological values were assigned to specific attributes which can be seen in the subsequent figure (see

Figure 4): The measured skin conductivity is represented by the height of the column, the skin temperature by the color of the column. The software also provides additional project-based visualizations. The perception of stress, for example, is represented by a red-colored head of the visualized icon, respectively the hiker.

6.1 Pre-Study for dynamic-continuous sensor data

Before conducting the main study, a pre-study was set up to check the functionalities of the GeoVisualizer. This was done in the context of a hike through the Palatinate Forest, where a test person had to wear the sensor devices. The results have shown that the functionalities of the GeoVisualizer are suitable to illustrate the emotional arousal in multiple ways for further analyzing processes. Furthermore, the graphical analysis provides comprehensive possibilities to detect and display emotional stress, or in case of a solely high skin conductivity, exhaustion.

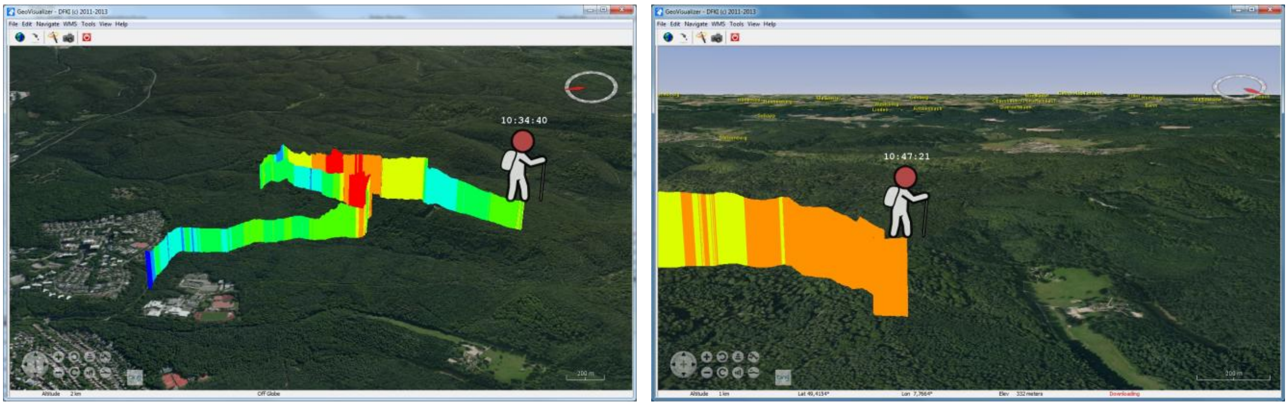

Figure 4: Virtual Globes enable visual analysis from different angles (Source OWN FIGURE 2013)

6.2 Static-continuous sensor data – Results and visualizations

In the main study, two different scenarios were designed. First scenario was a test setup with static sensors that were subsequently visualized with the GeoVisualizer. The limitation to a determined location also offers the advantage that no location inaccuracies due to unstable GPS signals will occur. The test people were equipped with the BMS Smartband and visited a football match of the local team of Kaiserslautern on the 30th of September 2012. In this test scenario, psychophysiological measurements of the volunteers were taken and validated in the aftermath. The emotional reactions of the participants can easily be connected to the course of the match. Based on the presentation of the data, the correlation of emotional stress reactions and specific situations in the match can be identified (e.g. goal and red card). Both goals show effects in the physiological data. Due to the chosen visualization mode (see Figure 5), it was easier to illustrate specific situations (peak of the 3D bars to the right in Figure 5a & b) as well as the time period before the situation (3D Bars scroll from the right to the left over time). The influencing factors for the participants were mainly limited to the events of the match, because the location was static. Furthermore, video data from the match as well as the match-ticker were used to compare the specific events with the measured data sets.

6.3 Dynamic-continuous sensor data – Results and visualizations

In addition to the first experiment, the second one is characterized by using a dynamic component, namely the walk down from the football stadium to the inner city of Kaiserslautern. The participants were equipped with the same instruments, but additively with a GPS logger, which was used to locate the collected physiological values.

After the end of the match, the study participants went on a pre-defined route to the inner city together with the other spectators from the stadium (see Figure 6). The first third of the walk was right in the flow of the crowd, while the rest of the walk was in a quieter area of the city. The data shows that the arousal level of the person’s stress in the early part is much higher than at the end of the trail, which was less crowded. Based on these measurements, it can be observed that there is a connection between the stress signals and the local circumstances of the route (Fig. 6 a). By creating a density map with places of stress reactions, critical points of the walk were pointed out. Those were mainly in the first part of the route where a dense crowd still was present (risk of congestions). These congestions reducing the walking speed and the feeling of being trapped in a crowd are impacts to induce emotional stress for the participants. People of the research group without measurement devices confirmed this impression of the crowded and congested route in a retrospective interview. The findings are useful hints in further urban planning projects, like evacuation scenarios.

In addition, this approach was used for two other participants, who had to walk a pre-defined route while passing some touristic and architectural hot spots of the city. Due to manifold influences on the participants during such a trip, it is still very complicated to detect specific urban patterns. Results of this study example will be used for further research.

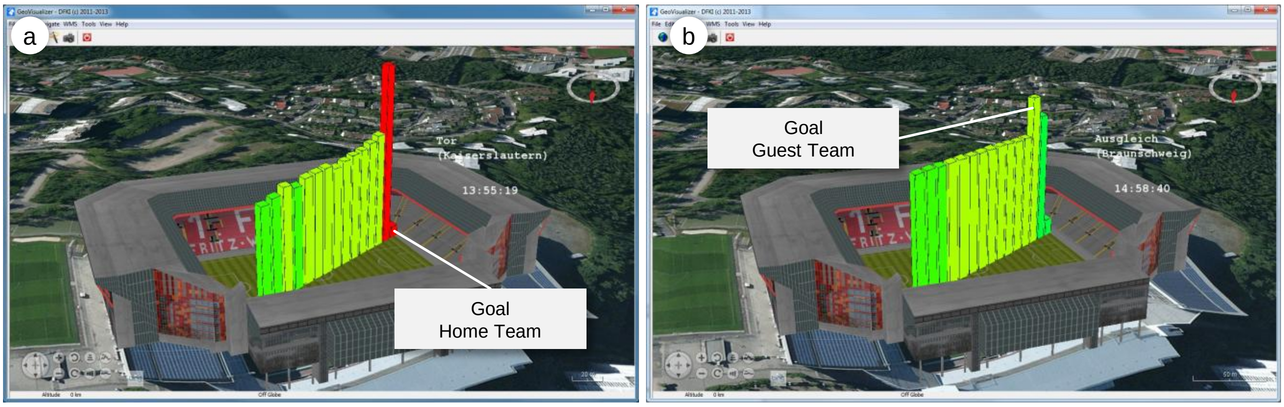

Fig 5: Visualization of sensor data during a soccer match. „Scrolling 3D Bars“ help to identify on which specific situations emotions occur for the participants (Source OWN FIGURE 2013)

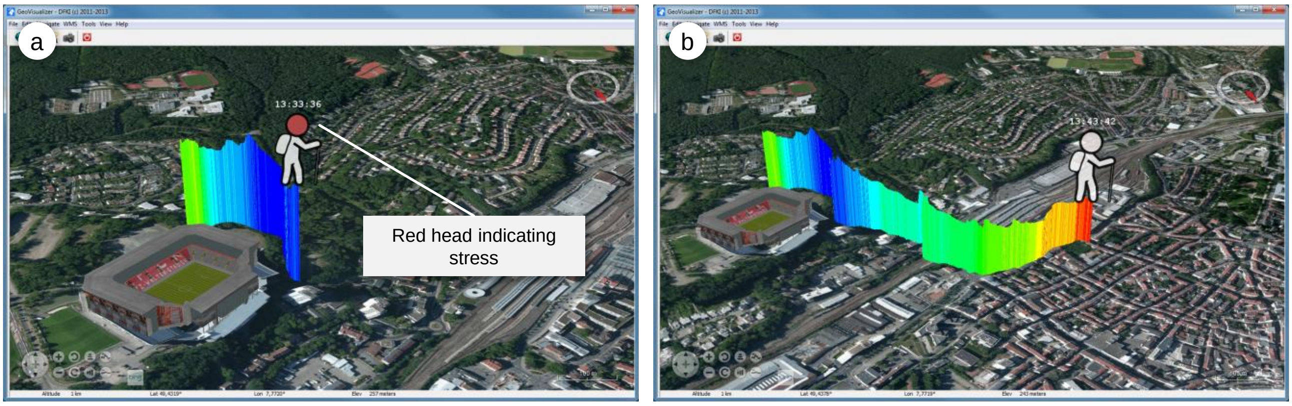

Fig. 6: Enhancement of the „Animated Polyons“ with a specific user-icon. The reddish head (a) emphasizes the stress-reaction during the congested street part (Source OWN FIGURE 2013)

7 CONCLUSION

The GeoVisualizer turned out to be a suitable tool for the complex requirements of the representation of (human) sensory data for spatial planning. This includes in particular the modular functionalities and the various display modes for the observation of phenomena in urban spaces during time. The previously mentioned approach offers chances for planners to allow emotional monitoring and to use its results for urban planning. The study cases gave a glance on how such approaches can be integrated in planning processes.

For both study cases, the GeoVisualizer was able to execute the complex analysis tasks. It reduces the complexity of the previously used workflow: It is an easy-to-use tool, which has a modular structure and allows quick changes between the different modes of visualizations. This offers opportunities for planners to perform spatial monitoring using multiple spatial data sources. Hence, human sensory data, characterized by a high spatial and temporal complexity, can be visualized easily and in a sophisticated way. Communication of these sometimes very complicated facts and results is easier with this kind of presentation, especially for laymen. Presenting this system on an open scientific night (Lange Nacht der Wissenschaft), a large number of citizens were interested in this new approach. During the event, a large number of visitors gave positive feedback that GeoVisualizer is a kind of catalyst to transform complex data in an easy, transparent and understandable format.

In the future, there will be more visualization features for the complex human sensor data analysis: The direct integration of human-sensor measurements without a primary use of statistical programs is the main goal. In addition, an automatic creation of small video clips for a retrospective assessment of stress responses is a further goal as well as the integration of other (environmental) sensor data via a SensorML interface in order to achieve a better understanding of the processes and interactions in the system of human sensory data and the environment.

8 ACKNOWLEDGEMENT

The authors are thankful for the support of German-Egyptian-Scientific-Program (GESP), founded by DAAD and STDF, and the 1.FC Kaiserslautern e.V. for the support during the research. The authors would like to express their gratitude to German Research Foundation (DFG – Deutsche Forschungsgemeinschaft) for supporting the project "Development of methods for spatial planning with GeoWeb and Mobile Computing (Städtebauliche Methodenentwicklung mit GeoWeb und Mobile Computing)". Parts of this project were co-funded by the European Framework Program 7, under challenge ICT-2009-6.4 ICT for Environmental Services and Climate Change Adaptation of the Information and Communication Technologies program, project number 247708 (SUDPLAN).

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